Observational and Theoretical Foundation for the Dynamics in a High-resolution Sea Ice Model

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LONG-TERM GOALS

The overall goal of this collaborative effort is to provide the observational and theoretical foundation for ice dynamics in a high resolution sea ice model, PIPs 3.0, based on the concepts of sliplines and granular plates and the use of direct field measurements and remote sensing assets.

OBJECTIVES

There are 3 main objectives in this project:

- Further understand the scale interaction between the multiple floe scale (<10 km), the regional granular continuum scale (10-200 km), and the sub-basin scale (>200 km).
- Understand the stress propagation through sea ice by direct measurements from a regional stress array (50-200 km), and use results to estimate the ice strength parameter, P*.
- Create at least five test cases for model evaluation.

APPROACH

Our approach is based on the fundamental assumption that regional ice motion is controlled by a system of sliplines and aggregate plates, made of individual ice floes. This assumption is the result of insights gained from observations made during the Sea Ice Mechanics Initiative (SIMI) and the Surface Heat Budget of the Arctic Ocean (SHEBA) field programs (Richter-Menge and Elder,1998; Overland et al., 1998). These observations were derived from stress and deformation arrays and satellite-derived motion vectors. The objective of this effort is to further assess the validity of this concept and extend it to the basin scale. A number of coordinated activities are underway to achieve this objective: a) continued analysis of the SIMI and SHEBA data sets, b) deployment of another stress and deformation buoy array, and (c) application of a host of remote sensing tools. Test cases for the evaluation of the PIPs 3.0 model are chosen by studying these combined resources to determine

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14. ABSTRACT
The overall goal of this collaborative effort is to provide the observational and theoretical foundation for ice dynamics in a high resolution sea ice model, PIPs 3.0, based on the concepts of sliplines and granular plates and the use of direct field measurements and remote sensing assets.

15. SUBJECT TERMS

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periods of significant ice motion activity.   Observations and model results are compared by considering the individual components of the stress divergence term, which include the effects of normal compression, shear stresses, curvature of the sliplines, and hardening of the ice cover in response to continued wind forcing.

In addition to extending the scale of our direct observations of stress and deformation, the buoy array is designed to provide information on the ice strength parameter, know as P* . P* is a key component in the PIPs and other sea ice dynamics models, as it determines when ice failure occurs in the model. The buoy array has been designed to measure the speed of the compressional waves during convergence of the ice cover against a coastal boundary, to give a direct estimate of P*.

WORK COMPLETED

We completed the revisions to papers that describe (a) the role of summer ice dynamics in the surface heat budget (Richter-Menge et al., a) and (b) the relationship between in situ measurements of ice stress and satellite-derived ice motion observations at the regional scale (Richter-Menge et al., b). Both have received final acceptance for publication.

We conducted further analysis of the satellite imagery data taken during SHEBA, specifically focusing on the case studies selected for the evaluation of PIPs 3.0 (McNutt et al, submitted; McNutt et al, 2001).

We participated in the PIPs 3.0 meeting, held during this fiscal year, making presentations on our improved understanding of ice dynamics at the regional scale and presenting case studies for model evaluation.

We attempted to a deploy a set of autonomous buoys in the Beaufort Sea pack ice during the fall of 2000, using Prudhoe Bay, AK as a base of operations. These included 9 stress/position ARGOS drifting buoys, one meteorological station and one thermistor string to measure the time evolution of ice conditions. The stress buoys are designed to make measurements through one winter season and the met and temperature stations are equipped to report for 2 years. Due to poor weather conditions, we were unable to install this equipment. We have now secured a place on the *CCCS Sir Wilfrid Laurier* and will use this platform to deploy our equipment in the fall of 2001.

RESULTS

The key result from our work during this review period derives from the analysis of SAR and AVHRR satellite imagery data taken during the SHEBA field experiment. Unique to this effort is the application of a combination of analytical techniques, including reinitialization of the RADARSAT Geophysical Process System (RGPS) in January 1998. This approach permits an investigation of the sea ice dynamics in both the Seasonal Ice Zone (SIZ) and Perennial Ice Zone (PIZ), allowing us to differentiate the regional contribution of each ice type to the overall deformation in the Beaufort and Chukchi Seas. The SIZ is defined by the region that contains open water or a relatively low concentration of ice floes in the summer and mostly first-year ice in the winter. The PIZ consists of a relatively high concentration of ice ($\geq$ 90%) of multiyear ice throughout the annual cycle.

In the current analysis, the period from 13 January to 18 February was selected. This period coincides with 2 of the tests cases we have selected for the evaluation of the PIPs 3.0. The data demonstrate that the largest percentage of convergence, throughout the period, appears in the SIZ. Activity in the PIZ was not significant until later in the period. The differences in the timing of the deformation in the SIZ and PIZ suggests that the ice in the SIZ, which is relatively younger and thinner, is weaker and initially easier to deformed. As the ice in the SIZ becomes thicker, primarily due to re-distribution, the stresses are transmitted into the PIZ, and the regions begin to respond to the forcing as a continuous surface. These results continue to support the hypothesis that the fundamentally granular ice cover behaves as a mechanical continuum at a regional scale of 10 km to 150 km (Overland et al, 1998; Richter-Menge et al, accepted for publication, b).

IMPACT/APPLICATION

The result of a measurable relationship between ice stress and deformation is a strong indication that our goal of applying direct observation from field measurements and satellite imagery to validate the model results from PIPS 3.0, and other high-resolution models, is achievable. We are specifically interested in considering the rheology used to describe the mechanical behavior of the ice cover, which is a fundamental component of the model's governing equation. Direct validation of the rheology is likely to lead to improved modeling capabilities, including increased model resolution. We will focus our evaluation on the 9 km grid resolution/multi-thickness version of the developing PIPS3 model. A workshop on sea ice dynamics, held last year (Overland and Ukita), suggested that this level of physics is important to resolve regional (50-300 km) processes.

TRANSITIONS

These results will be used to develop and validate the latest version of the Navy's Polar Ice Prediction System model. We are working directly with the modelers involved in this project to determine and assess validation tests.

RELATED PROJECTS

1) SHEBA ice stress and deformation measurements are also being used in the SHEBA project, which is focused on improving models of climate variability. The SHEBA program is sponsored by NSF and ONR. Our work in this program is focused on improving the understanding of the processes that govern ice motion, which are important for determining the thickness distribution of the ice cover. The thickness distribution of the ice cover has a significant impact on heat and energy exchange between the atmosphere, ice, and ocean.

2) One of the PIs (JR-M) is working with Mark Hopkins (CRREL), who is receiving support from NSF and NASA to continue development of a discrete element model of the ice cover. This model is unique in its ability to consider floe-floe interactions and provide a more detailed characterization of ice distribution.

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